2016

Effects of Salinity and Chlorophyll on Underwater Optical Communication and Detection

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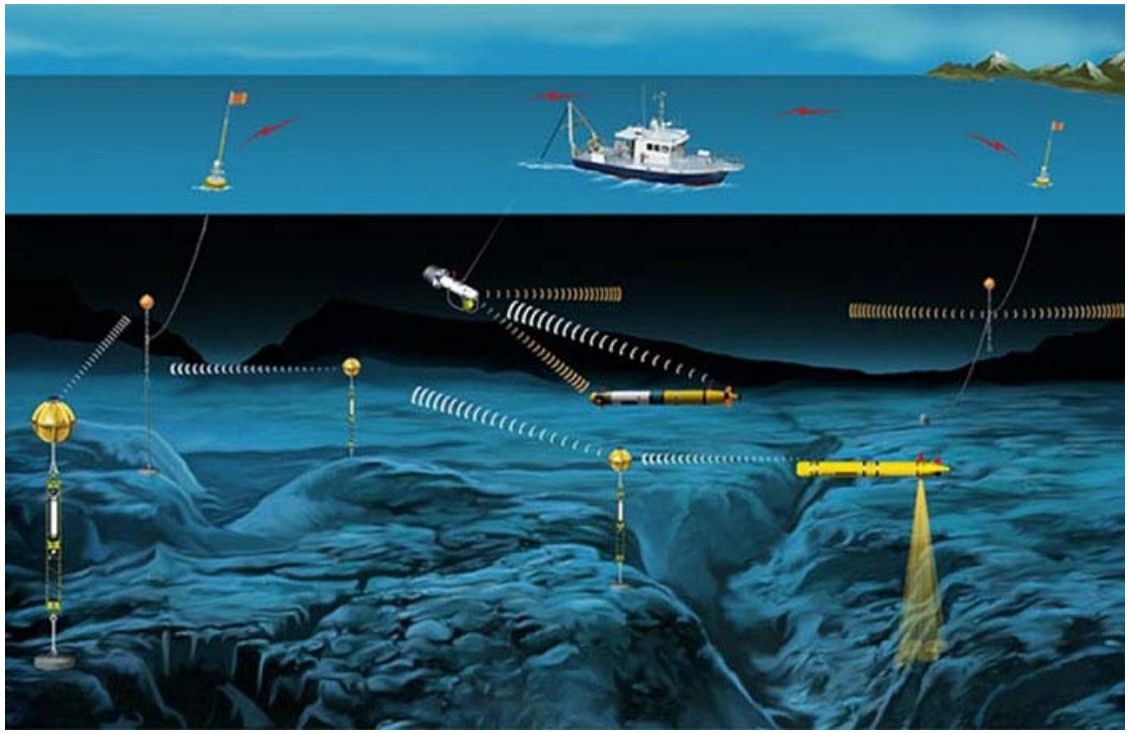
Support from the NPS Foundation is highly appreciated.

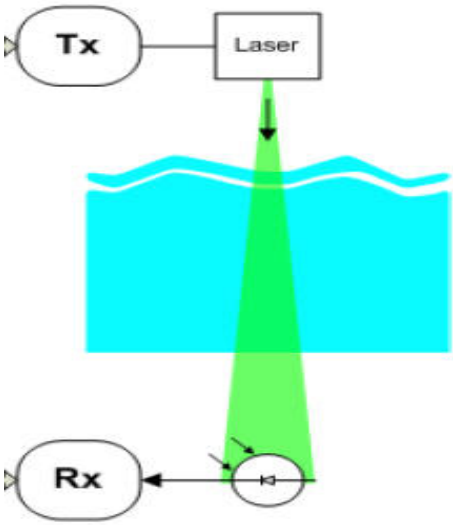
The Problem / Opportunity

- What is the effect of ocean environment such as salinity and Chlorophyll on the underwater optical transmission?

- This project has contributed to find an alternative underwater detection/communication technology to underwater acoustics.

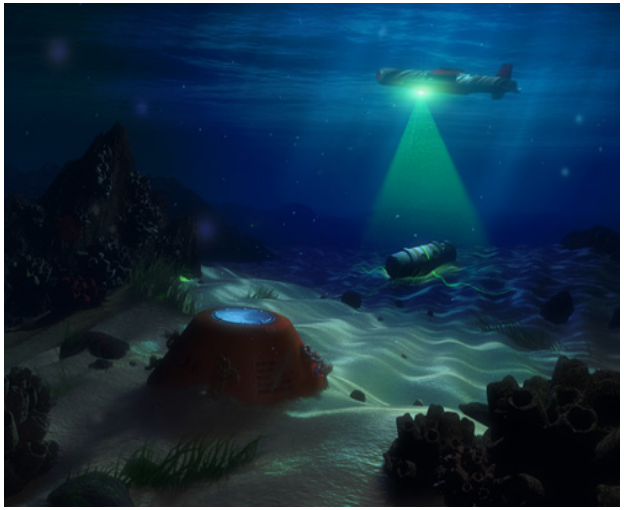
Underwater Optical Communication





https://images.search.yahoo.com/yhs/search;_ylt=A86.JyIuRzpWXTIA_7QnnIlQ;_ylu=X3oDMTEzbHNxNnYwBGNvbG8DZ3ExBHBvcwMxBHZ0aWQDRkZVSUMwXzEEc2VjA3Nj?p=Underwater+Optical+Communication&fr=yhs-mozilla-003&hspart=mozilla&hsimp=yhs-003

MINE DETECTION



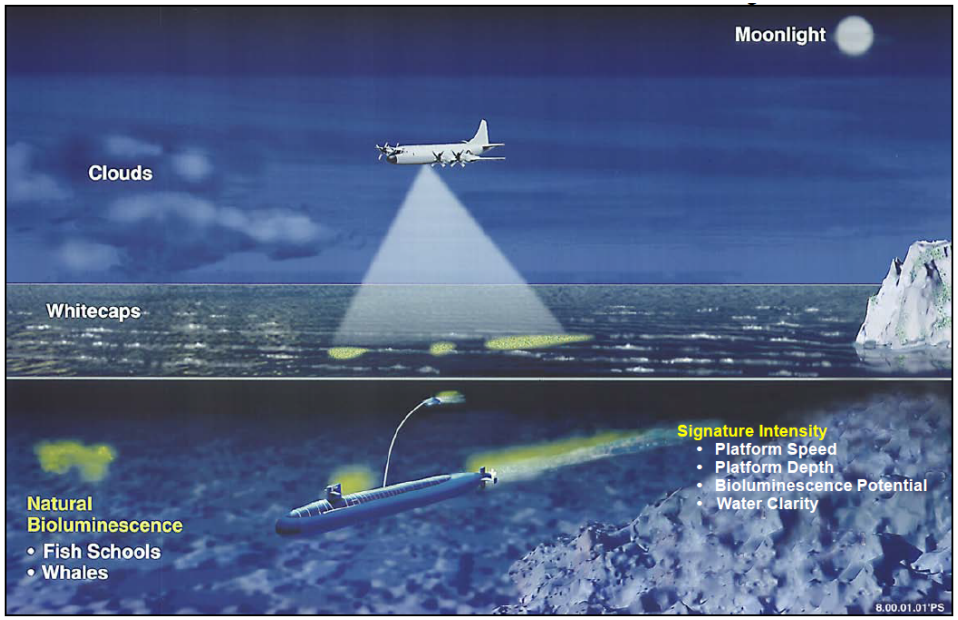
- Optical properties of the water are important in MIW

- Clarity of water column, vertically and horizontally, is vital in mine detection and classification.

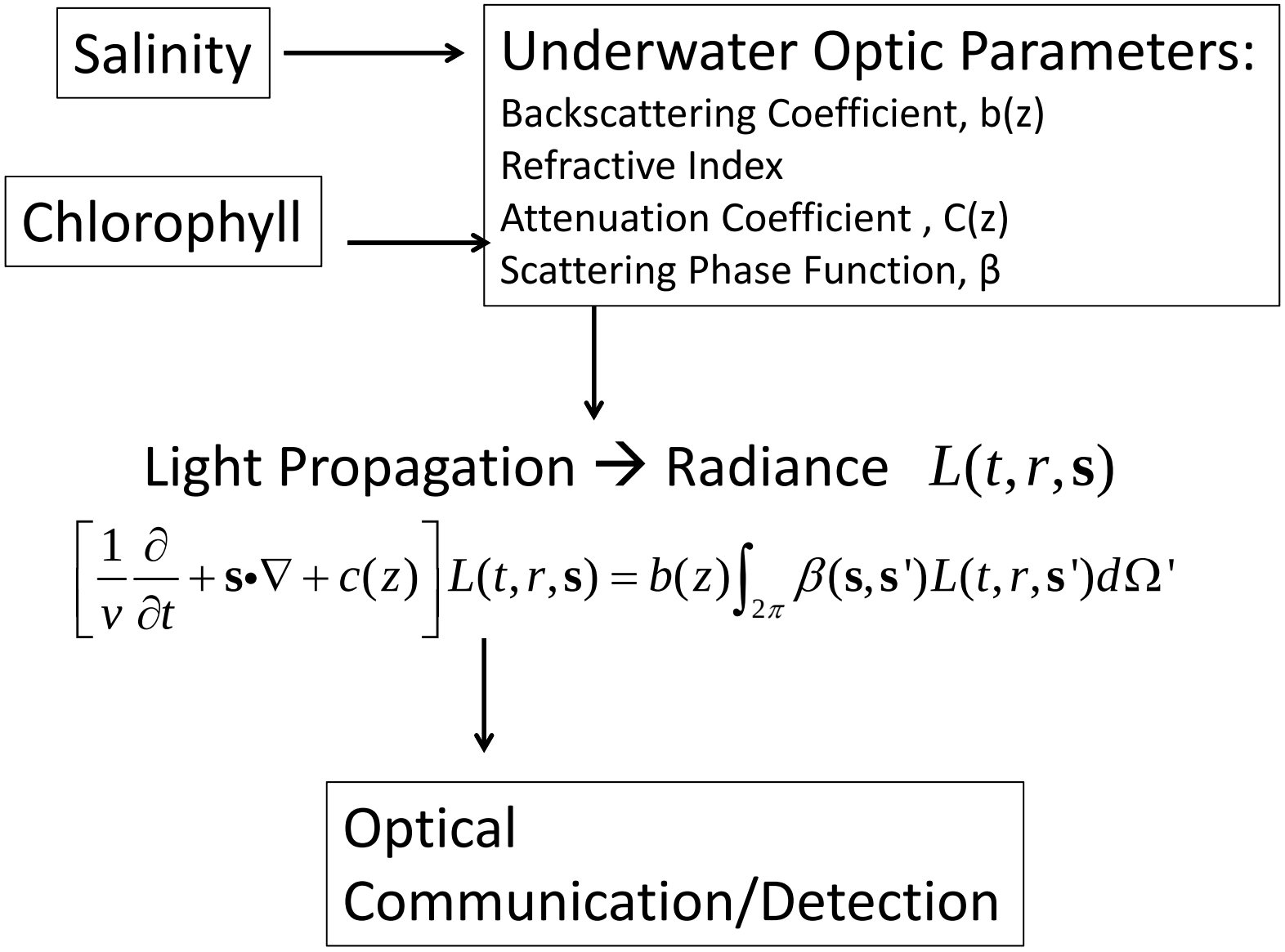
- Information on vertical structure of optical properties could provide guidance of deployment strategies of underwater sensors.

ANTI-SUBMARINE WARFARE (ASW)

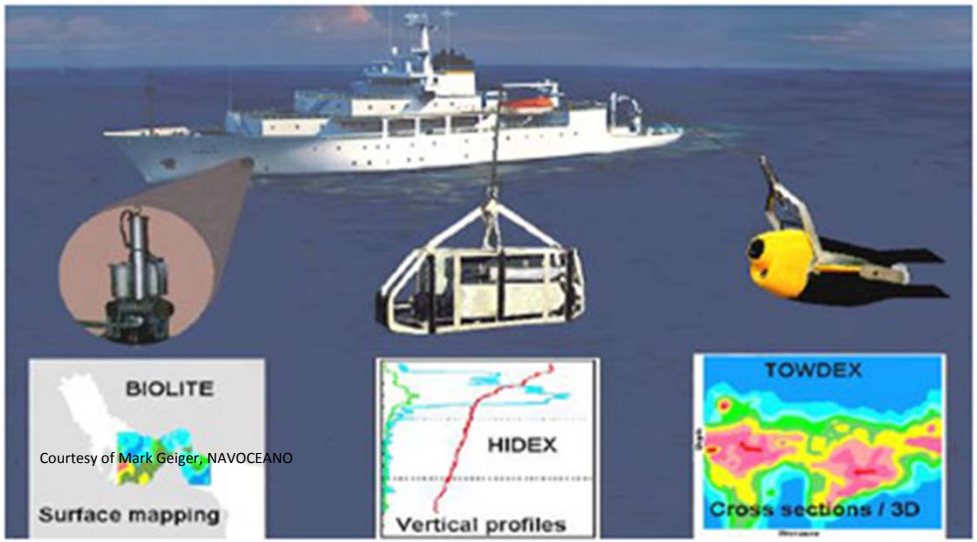
- Mechanically stimulated bioluminescence offers a mean of detecting and tracking surface and subsurface movement during the night.
- Complements acoustics - does not replace it.
- Prevalent in the acoustically noisy littoral where submarines must operate shallow.



Courtesy of Jeffrey Smart. (http://www.aticourses.com)


Salinity
Chlorophyll
Underwater Optic Parameters:
Backscattering Coefficient, b(z)
Refractive Index
Attenuation Coefficient , C(z)
Scattering Phase Function, β
Light Propagation → Radiance $L(t,r,\mathbf{s})$
$\left[\frac{1}{v}\frac{\partial}{\partial t}+\mathbf{s}\bullet\nabla+c(z)\right]L(t,r,\mathbf{s})=b(z)\int_{2\pi}\beta(\mathbf{s},\mathbf{s}')L(t,r,\mathbf{s}')d\Omega'$
Optical
Communication/Detection

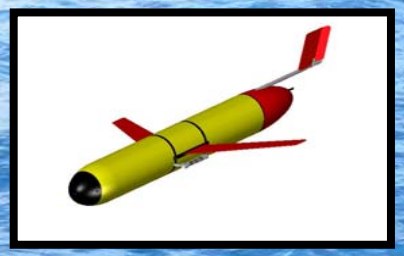
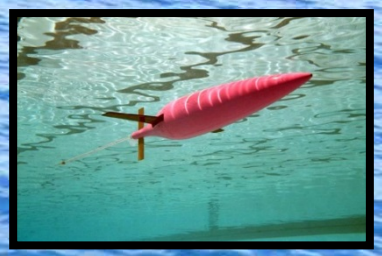
Instrumentation/Data Source



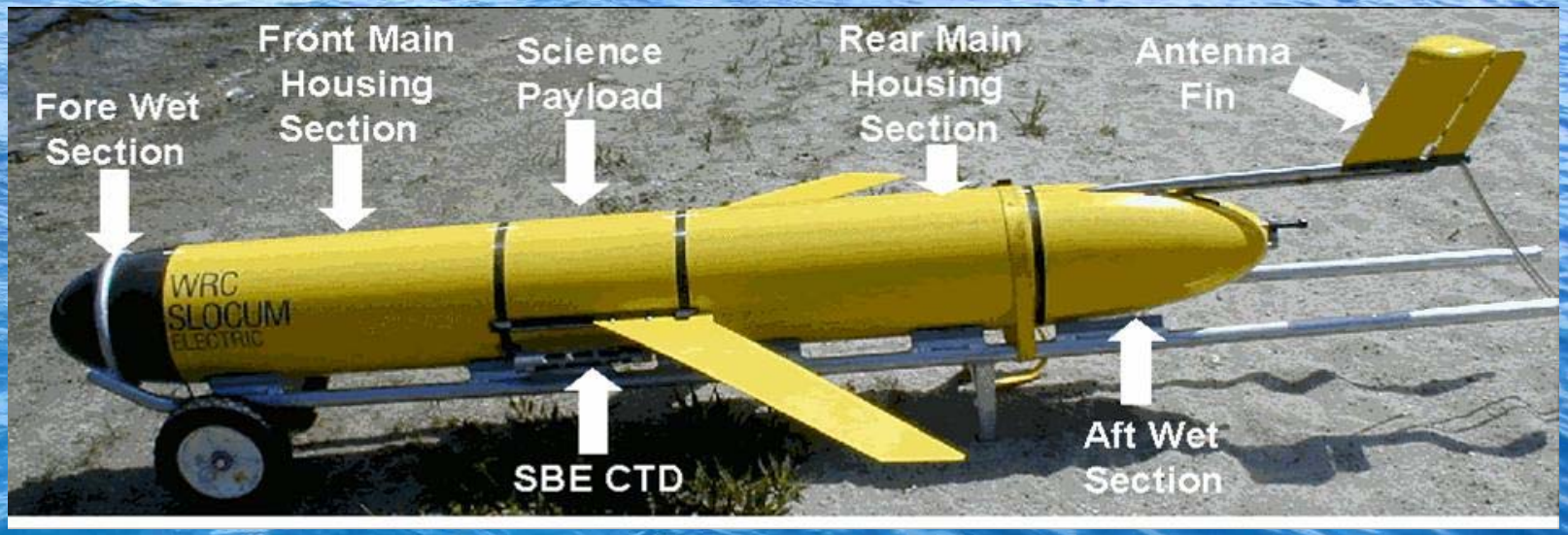
Courtesy of Mark Geiger, NAVOCEANO

NAVOCEANO bioluminescence instrumentation suite includes BIOLITE, HIDEX and TOWDEX bathyphotometers.

- At present, the HIDEX and TOWDEX have been put into storage. NAVOCEANO is working to replace the BIOLITE system with a new instrument called the Underwater Bioluminescence Assessment Tool (UBAT). UBAT is manufactured by WET Labs and currently still in the testing phase.

	Slocum Glider Teledyne Webb Research	Seaglider APL/UW
		
Steering	Active Rudder	Roll / Bank
Depths	4 to 200 m (option: 1000)	30 to 1000 m (option: 200)
Horiz. Speed	0.5 knots	0.5 knots
Nominal		
– Endurance	4 months	6 months
– Range	600 - 4000 km	4000 km
Power	Alkaline/Lithium	Lithium
Hull Dia.	21 cm	30 cm
Length	1.5 m	2.8 m (w/1-m antenna)
Weight	123 lb	110 lb
Comms	Iridium satellite phone	Iridium satellite phone

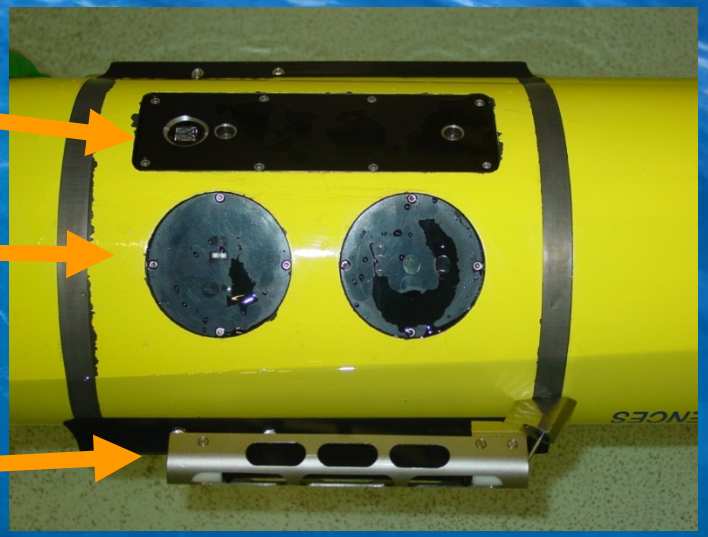
Slocum



Scattering and Attenuation

Environmental Characterization Optics

Conductivity, Temperature, and Depth



Instrumentation

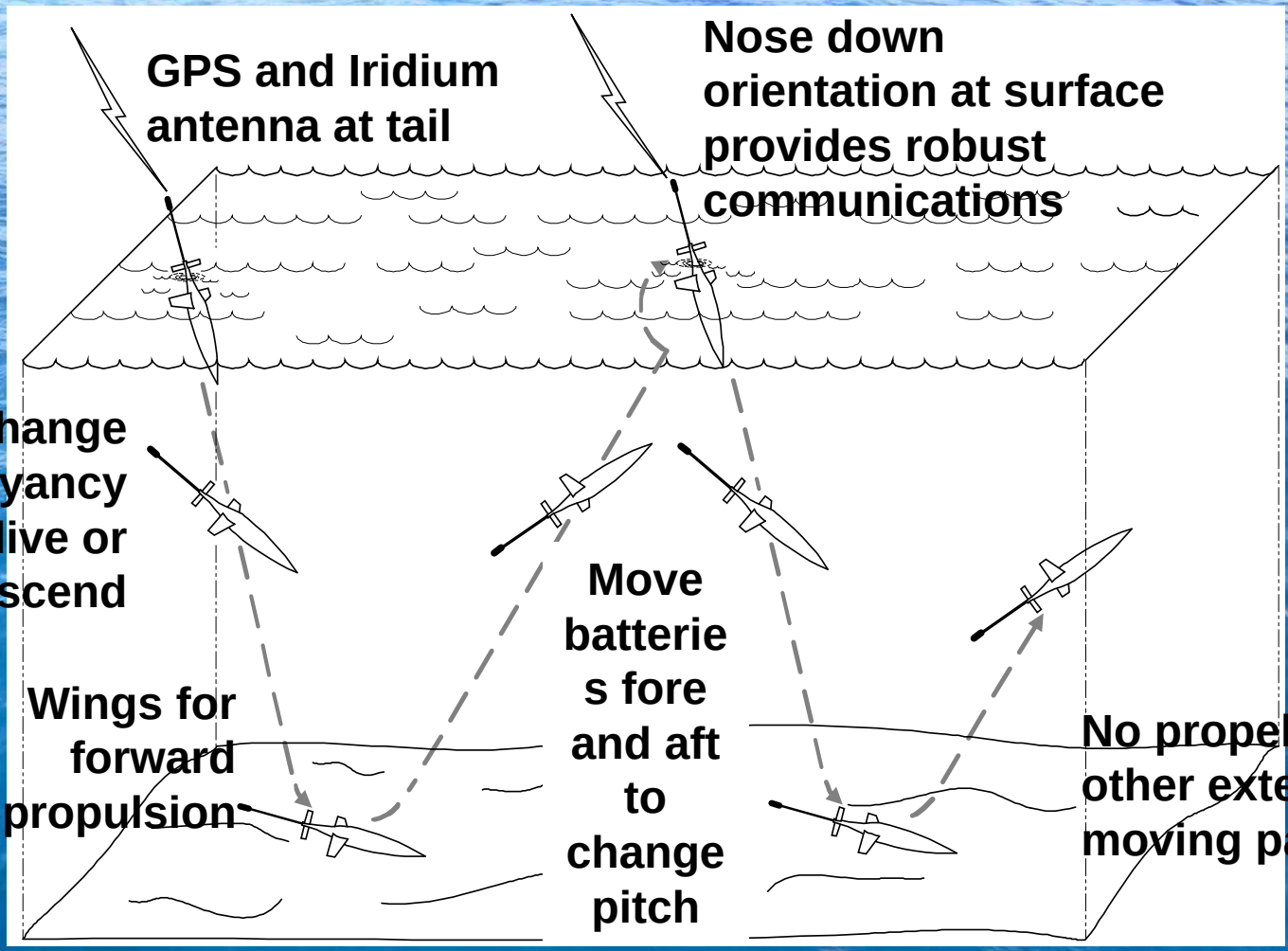
1) Seabird Electronics' SBE 41 CTD sensor

- Samples at 1 hz
- T accurate to .001 degrees C
- Salinity accurate to .005 PSU*
- Pressure accurate to 2 dbar*

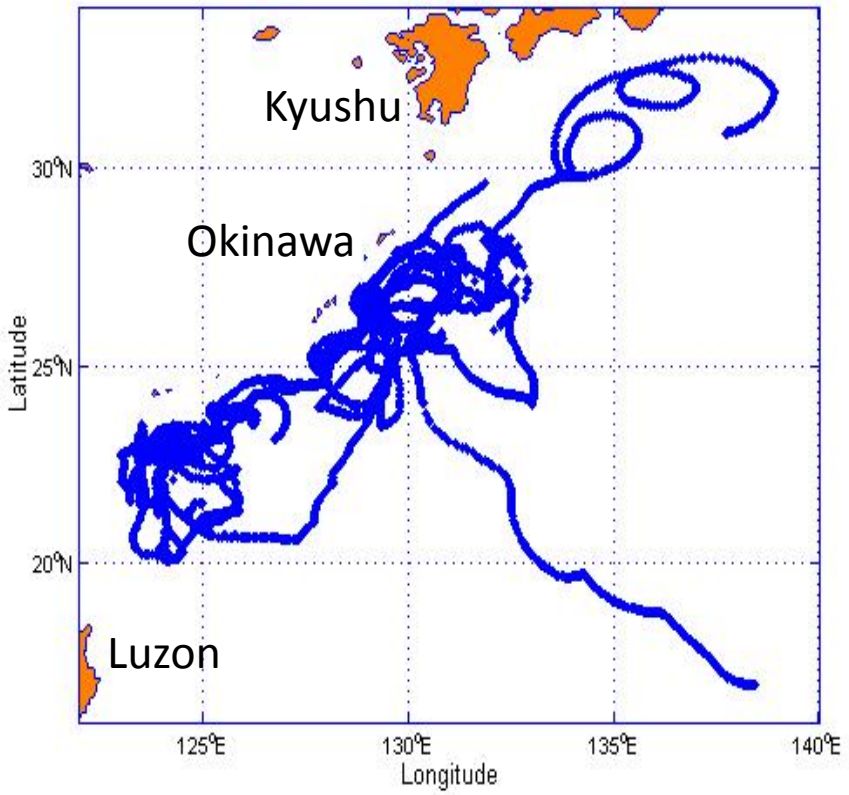
2) WET Labs, Inc ECO bb2fl optical sensor

- Optical Backscatter @ 470nm and 650nm*
- Flourometer: Chlorophyll-A @ 470 nm*
- Samples in top 300m to preserve battery life

Both sensors record and present data using NetCDF* data format which MATLAB manipulates quite easily



An Example of NAVO Glider Operations

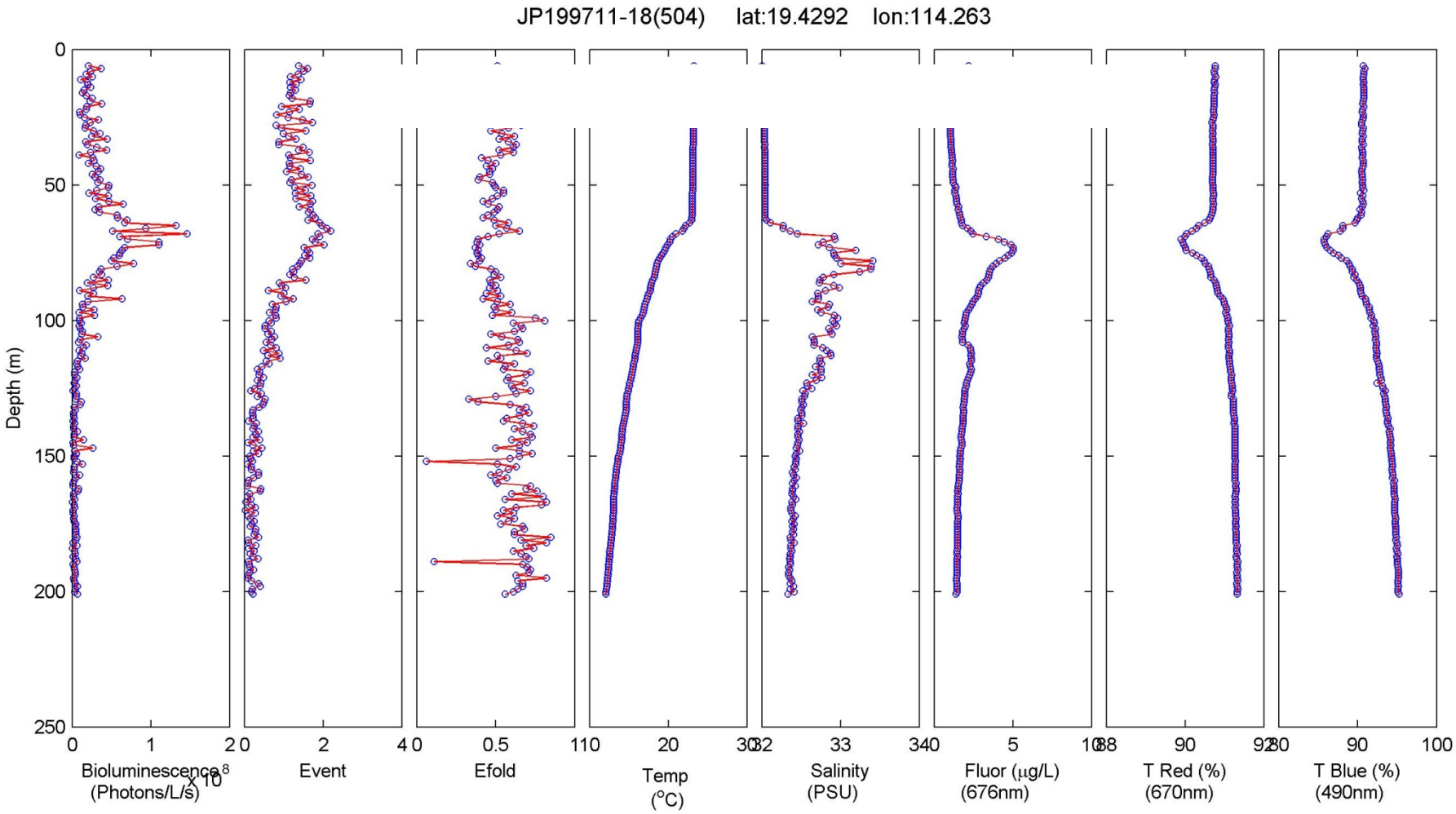


The 6573, in All Their Glory

Western Pacific

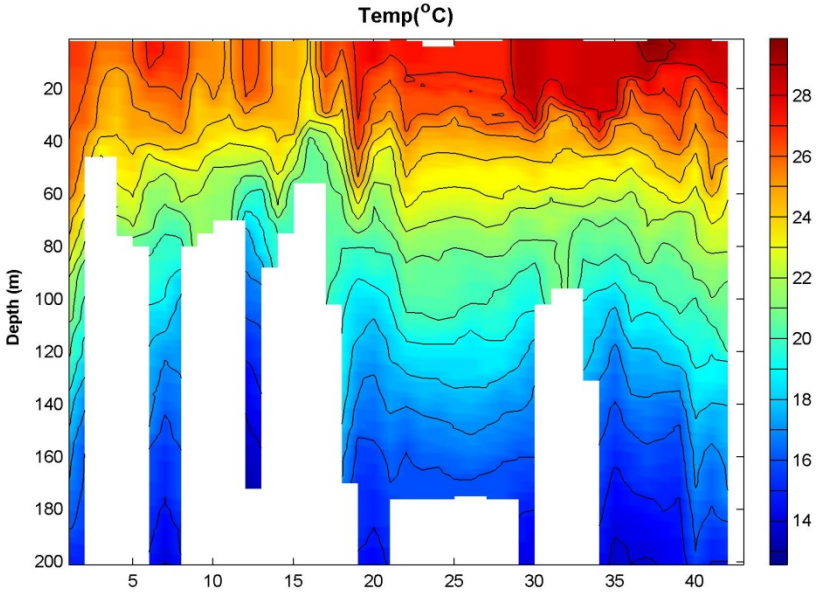
- Primarily east of the Ryuku Islands
- Dynamic area encompassing portion of Kuroshio WBC
- Total area: ~ 435,000 km^2

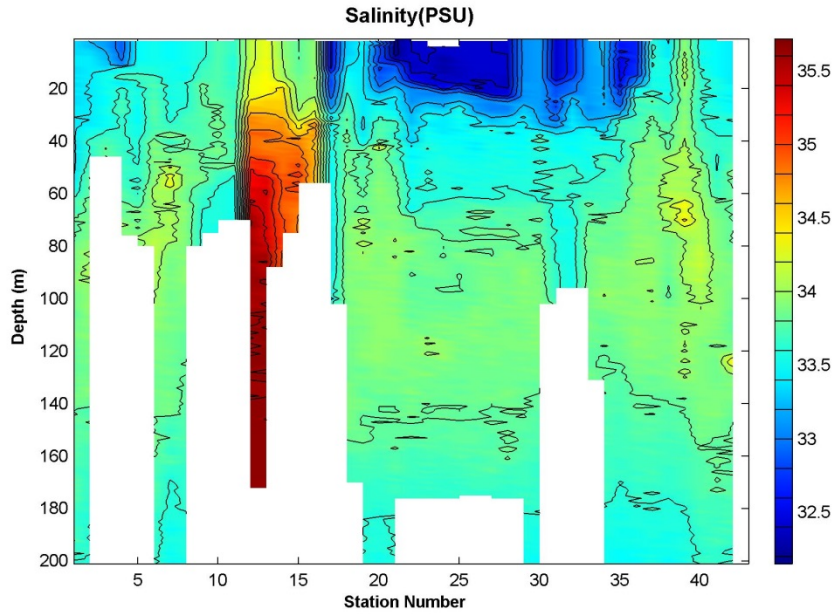
Example - Vertical Profiles

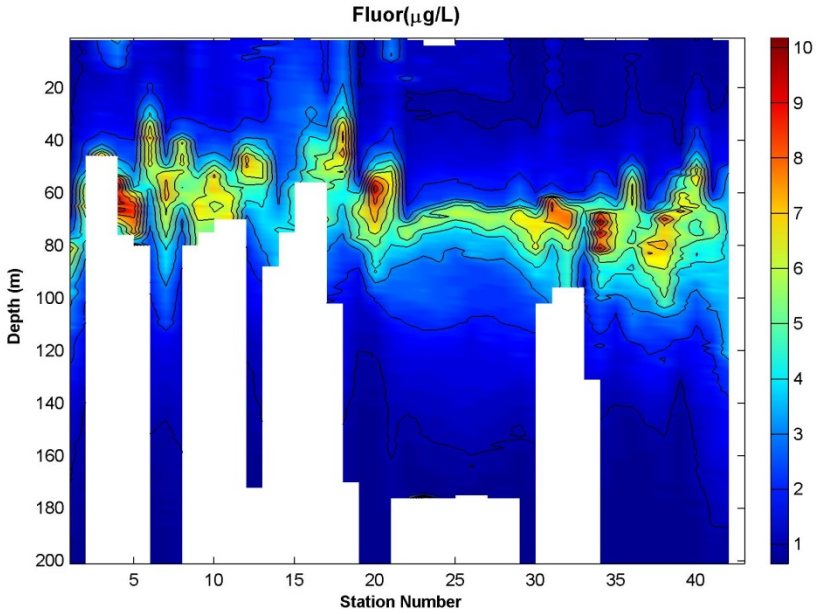


Location and time are not shown due to restricted data.

Vertical Cross Sections of (T, S, Fluorescence) Along Glider Tracks

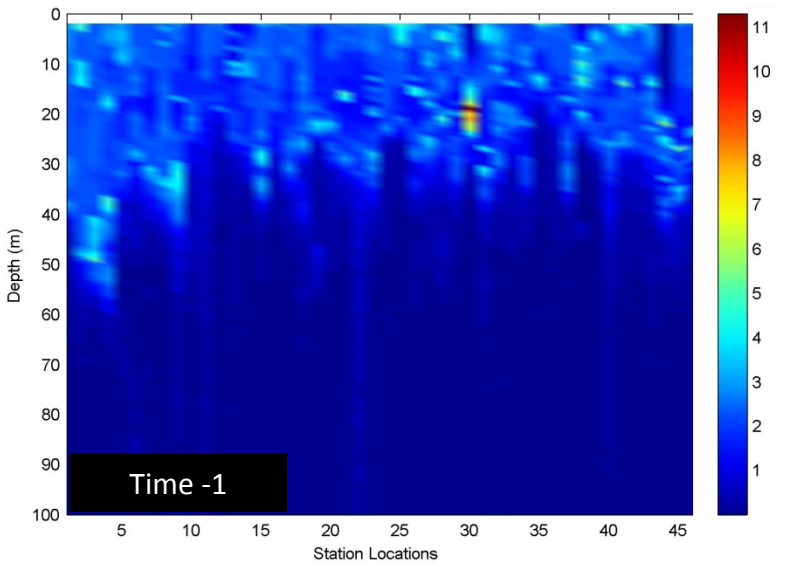


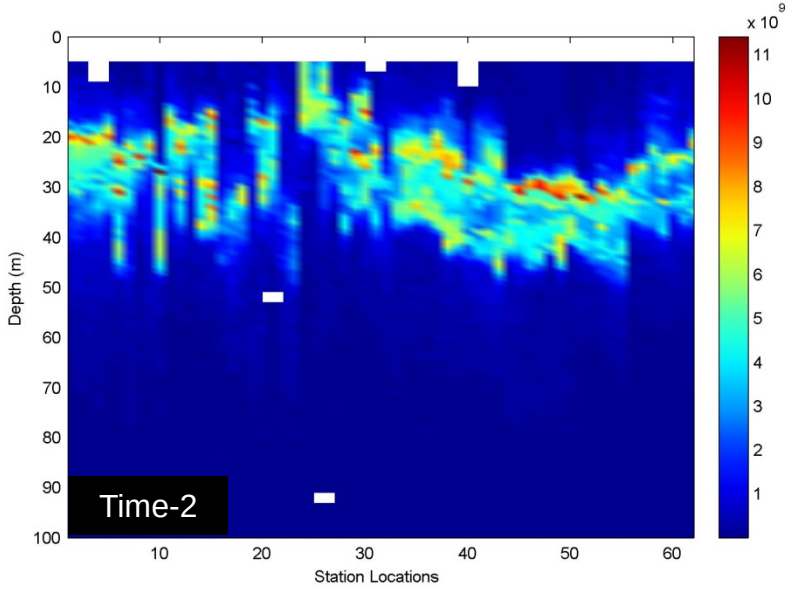


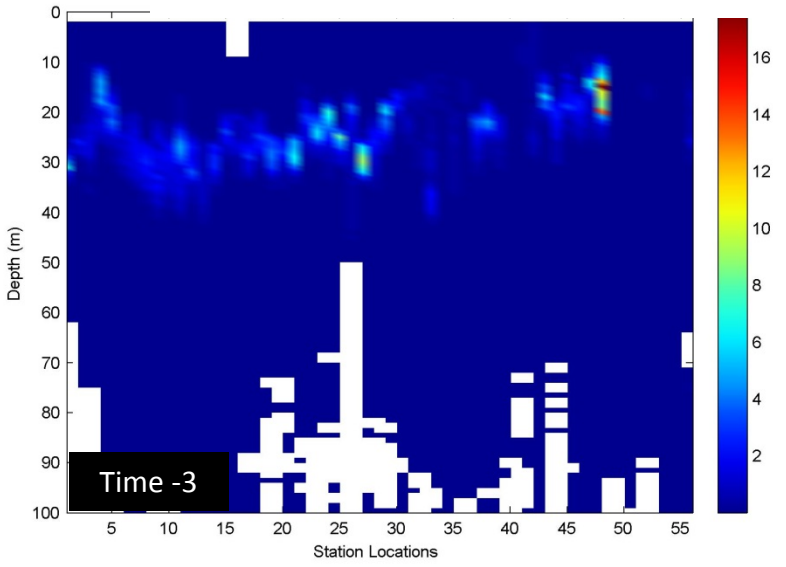


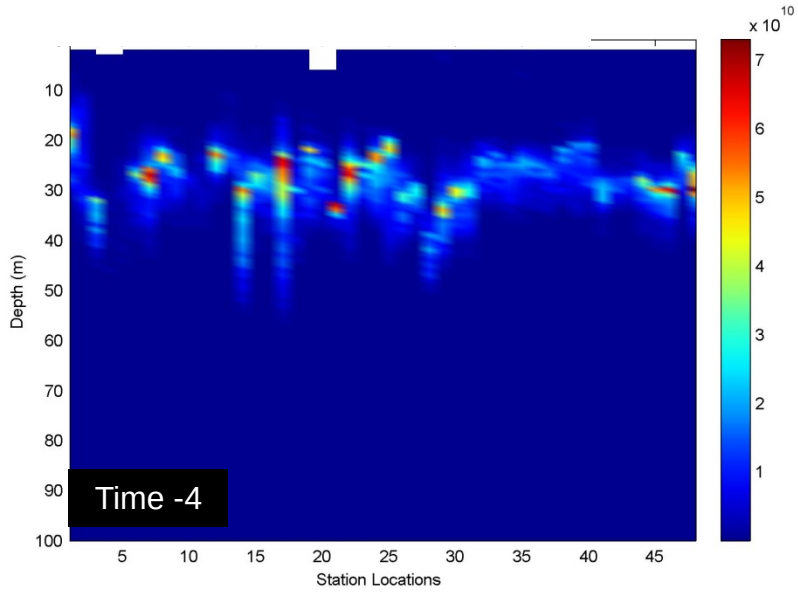
Vertical Cross Section of Bioluminescence Along Tracks

BIOLUMINESCENCE



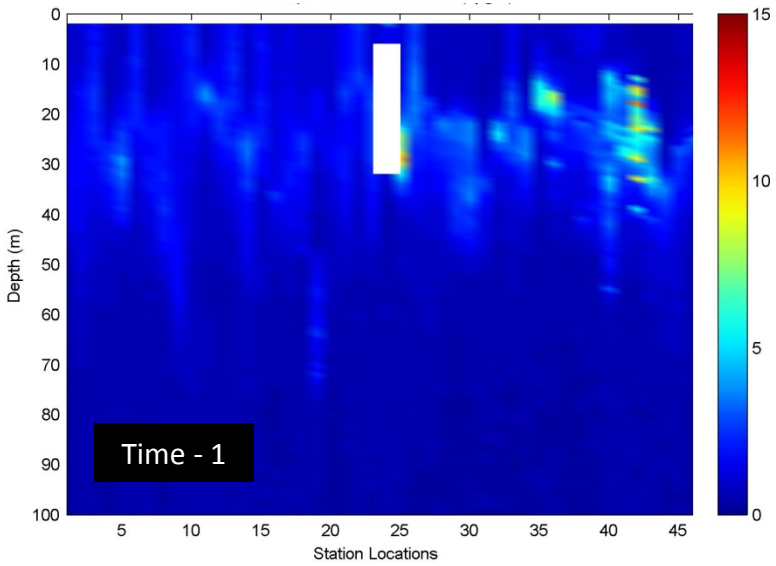


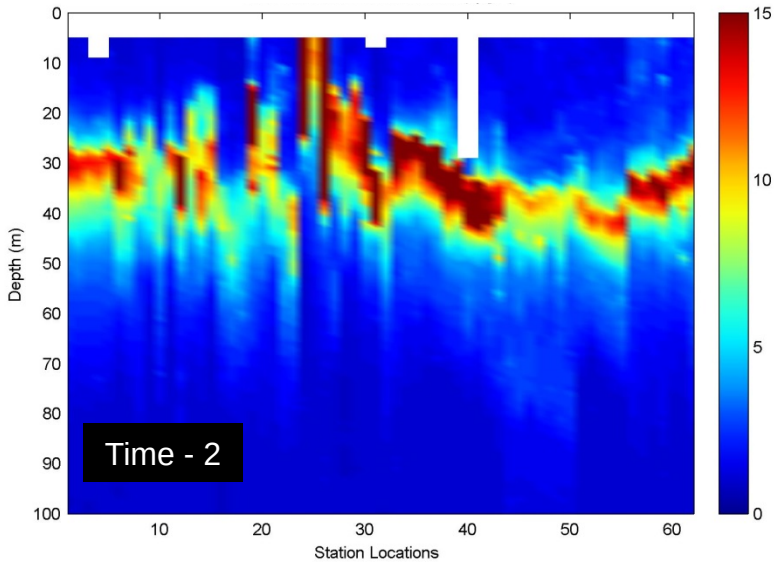


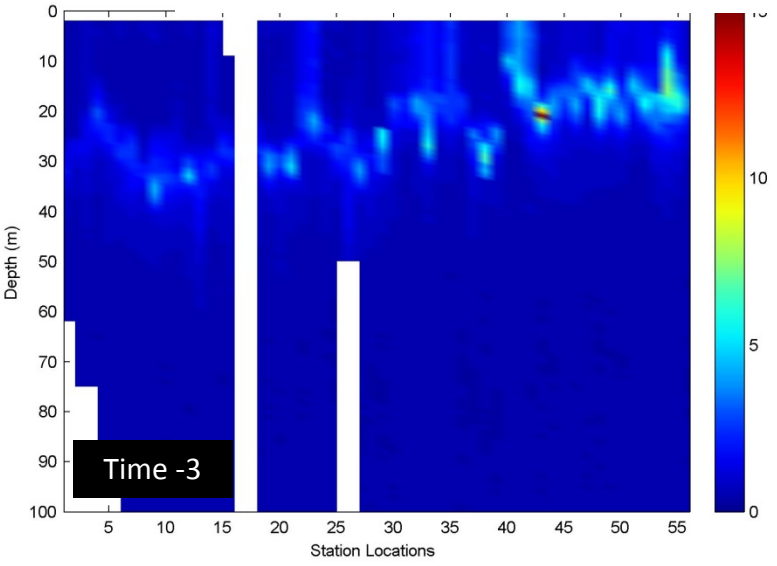


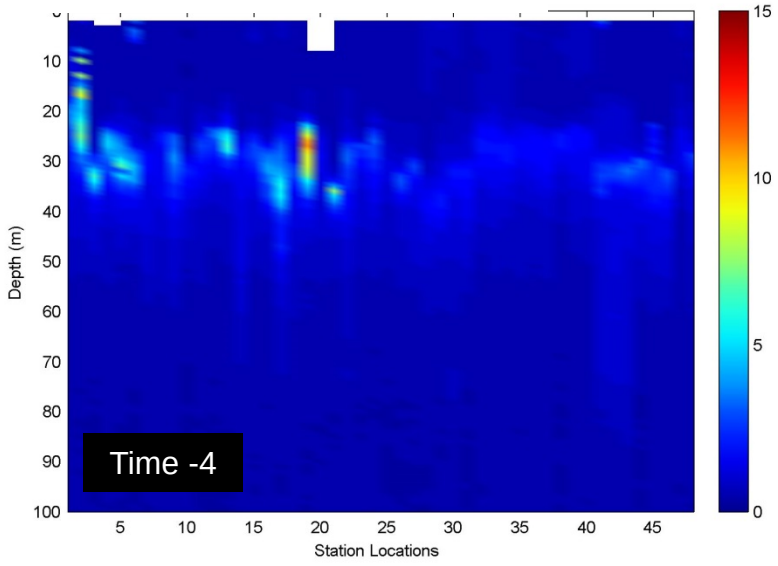
Cross Section of Fluorescence Along Tracks

FLUORESCENCE



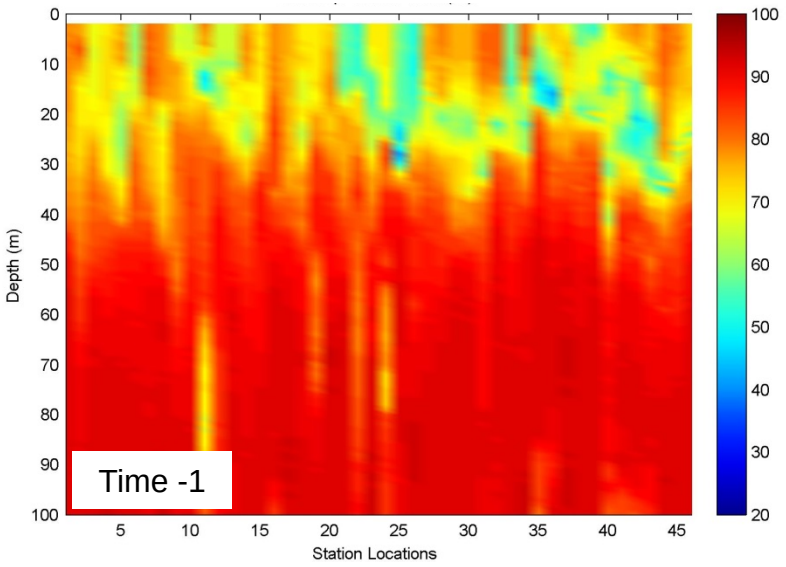


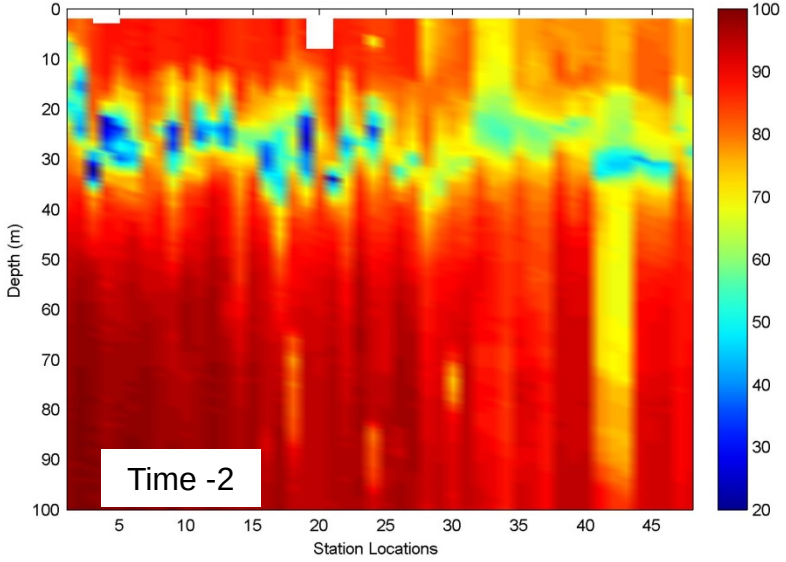


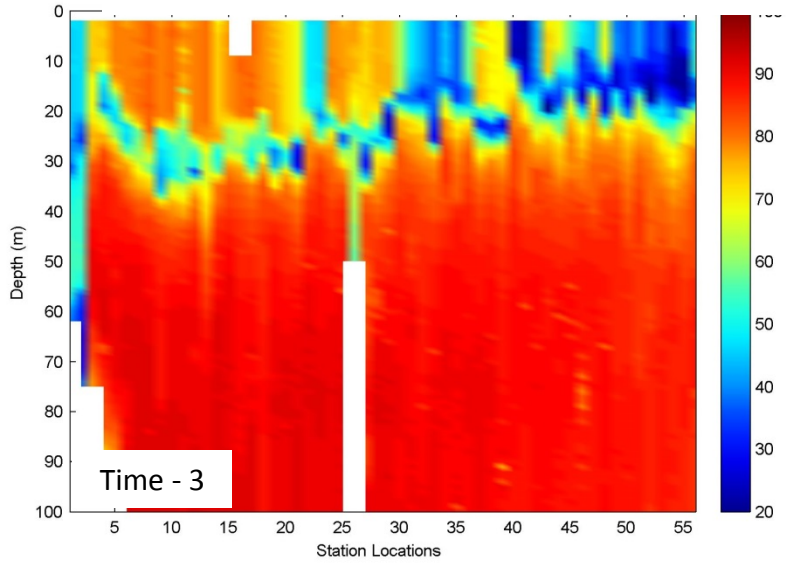


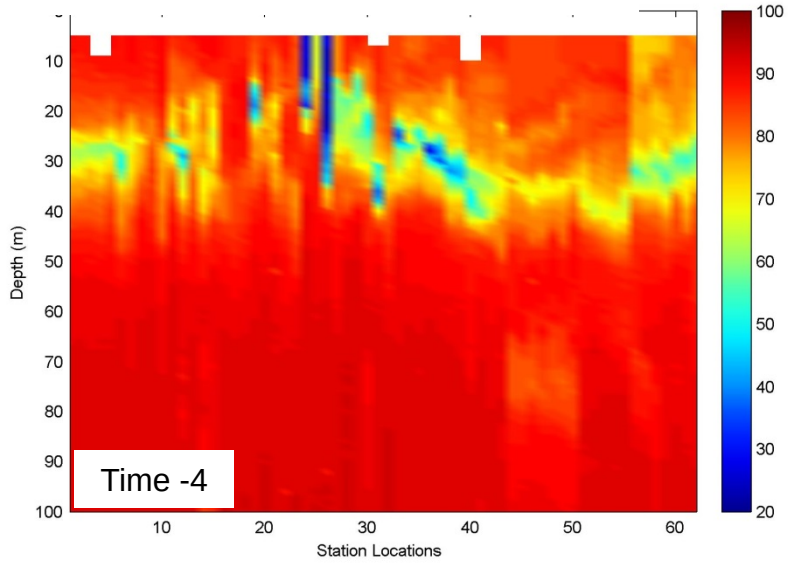
Cross Section of Transmission (490 nm) Along Tracks

BLUE (490 nm) TRANSMISSION









Three US Navy METOC/PO Theses in FY16

- Alexander J. Cullen, Environmental Effects on Underwater Optical Transmission in the Adriatic. MS in Meteorology and Oceanography, June 2016.

- Brian Breshears, Underwater Optical Transmission in the East Asian Marginal Seas for Warfare Operations. MS in Meteorology and Oceanography, June 2016.

- Ross F. Hammerer, Environmental Effects on Underwater Optical Transmission in the Arabian Gulf and the Gulf of Oman. MS in Physical Oceanography, March 2016.

Outcome of SEED & Funding Support from NPS Foundation

- OPNAV-N97 is the topic sponsor for this project in the Naval Research Program (NRP) → "**Transfer and Correlation Functions between Underwater Hydrographical and Optical Parameters**"

  The principal investigator will obtain $135,000 for FY17.

- Four USN students (LCDR Walter Young, LT Sabrina Cummings, LT John Martin, LT Eric Wishnie) are doing research on this project for MS degrees in FY17.

- Support from the NPS Foundation is highly appreciated.